Aboral Extrusion of Squid Pens by the Sea Star *Pycnopodia helianthoides*

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(2 Plates; 1 Text figure)

INTRODUCTION

THE BREAKING OF the aboral body wall of the sea star *Astropecten californicus* Fischer, 1906, which swallowed a large bivalve, *Donax vittatus* da Costa, 1789, is mentioned by CHRISTENSEN (1970: 58). Christensen assumed the breakage was due to the sea star being washed ashore and left to dry in the sun during low tide. Since previous reports had been based on dead and, in most cases, dried specimens, Christensen was convinced that fissures in body walls of these sea stars were of post mortal origin.

After spawning, dead and dying squid, *Loligo opalescens* Berry, 1911, are found in great numbers on the floor of Monterey Bay, California. Many of these spent animals become a temporary part of the diet of the sea star *Pycnopodia helianthoides* (Brandt, 1835).

In April, 1971, on the seaward side of the United States Coastguard Breakwater at the southwest end of Cannery Row, Monterey, California, a *Pycnopodia helianthoides* was found subtidally with the anterior end of the pen (or shell) of a *Loligo opalescens* protruding 3 cm out through its aboral surface. The pen was 8 cm distant from the madreporite, and it was not through the sea star's anus. Two of the sea star's rays were up over the disc, wrapped around the pen. When the pen was extracted, a white, fleshy substance, presumed to be partly digested squid material, came out of the slit.

An experimental feeding in the field of 20 to 30 fresh market *Loligo opalescens* to individual *Pycnopodia helianthoides* resulted in the observation of only one sea star with a squid pen protruding 5 cm through its aboral surface. Since the fed sea stars were unmarked, some may have moved out of sight beneath the rocks. A *P. helianthoides* fed a squid in the laboratory did not put the whole animal into its stomach as did sea stars in the field. An experiment was devised to determine whether *P. helianthoides* typically eliminates squid pens in the field by forcing them through its aboral surface.

METHODS

Five isolation containers for a series of subtidal tests were constructed from round plastic baskets tied together (Figure *1*). Each basket was 37 cm in diameter and 26.6 cm deep. A galvanized pipe was fastened to the baskets and served as a base. The baskets were covered with fine-mesh plastic screen to keep non-test sea stars from reaching into the baskets for squid (as was the case on the first test, run without the screen). Lids were pressed into the slightly tapered baskets. The isolation containers were light and easy to handle by divers using SCUBA gear, and were held in place on the bottom at 12 m depth by rocks piled on the frame. *Pycnopodia helianthoides* and fresh dead market *Loligo opalescens* were placed in the containers and checked periodically.

Squid chosen for experiments were 30 - 33 cm in total length. Four squid pens removed from the above averaged 15.3 cm and were 2.1 cm at the widest point. The pen is flexible on the posterior end. A rib running the length of the pen is larger and adds strength to the pen at the anterior end. This semirigid anterior section, approximately 7 cm long, terminates in a sharp point.

RESULTS

Five subtidal tests (Table 1) were run in the isolation containers. Of 11 observed feedings, 10 squids were totally ingested by the sea stars within 10 minutes.

Of 26 sea stars tested in the isolation containers, 7 were found (26.9%) with a squid pen protruding through their aboral surface; the average protrusion was 2.9 cm. The average time of emergence of pens was 22.7 hrs, the range 19 - 27 hrs. The sea stars were not observed continually: the longest period between observations was 23 hrs; the average period was 7 hrs. The only timed observation outside the isolation containers was 19 hours, with the pen protruding 5 cm (Figure *2*).

Out of 9 sightings of pen protrusion (including 2 outside the isolation containers), 3 pens were measured to be 5 cm out through the aboral surface. All sequential observations of pen protrusion of a given sea star showed the pen to be protruding the same or an increased distance with time.

Close inspection of the aboral surface of sea stars in 4 trials showed the squid pen protruding through the papulae of the aboral disk (Figures *2, 3*). The position of the protruding squid pen of each of 6 observations is indicated diagrammatically in Figure 4. In no case was the pen protruding through the anus.

In all but one case of observed pen protrusion 2 to 4 rays were curled up around the pen. When rays were found in this position, another sea star touched to the test animal's opposite and normally positioned rays elicited movement and subsequent withdrawal of the curled rays. The protruding pen was then measured. These same test sea stars were re-inspected 3 or more hours later and all had replaced rays around the protruding pen.

DISCUSSION

Subtidal testing indicates that after *Pycnopodia helianthoides* feeds upon *Loligo opalescens* the indigestible squid pen is frequently extruded through the aboral surface of the sea star. While the pen has not actually been seen in a state of dropping out of the aboral surface, indications are that it does. Since the semi-rigid anterior section of the

Table 1

Summary of Results from Subtidal Isolation Containers
November 27, 1971 to March 21, 1972
Isolation container tests

Test	Number of *Pycnopodia* tested	Number with pens protruding	Distance of pen protrusion (cm)	Total time of test (hrs)
1	3	1	1.0	23.5
2	5	1	5.0	43.0
3	5	1	2.0	47.7
4	6	2	2.0 3.5	51.5
5	7	2	1.5 5.0	23.0
Total and Mean Values	26	7	2.8	37.7

Explanation of Figures *1* to *3*

Figure *1*: Subtidal isolation containers

Figure *2*: *Loligo opalescens* pen protruding approximately 5 cm from the aboral surface of *Pycnopodia helianthoides*

Figure *3*: Aboral surface of *Pycnopodia helianthoides* prior to squid pen protrusion. Note stretching of surface surrounding papulae


Figure *1*


Figure *2*


Figure *3*